How do Black Bream move through the fish gate on the Vasse Surge Barrier?

Stephen J. Beatty[1], Richelle Addicoat[2], James R. Tweedley[1], Tom Ryan[1], Alan Cottingham[1], David Morgan[1]

[1]Centre for Sustainable Aquatic Ecosystems, Harry Butler Institute, Murdoch University

[2]Department of Water and Environmental Regulation, Government of Western Australia

Murdoch University | Harry Butler Institute

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Release of tagged Black Bream during the community fishing day.

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Summary

This study determined how Black Bream used the fish gate on the Vasse Surge Barrier by tagging them state of the art internal electronic tags. The tags, known as PIT tags, detected fish that passaged upstream and downstream through the fish gate over an 18 month period in 2017 and 2018. The local community helped us tag and release 322 Black Bream.

The study revealed that movements through the fish gate were unrelated to spawning activity of this species and supported early work that the Vasse Estuary is not a key breeding site; instead they use the Deadwater to reproduce. Up until May 2018, Bream passaged through the fish gate 440 times (265 downstream and 175 upstream). Black Bream preferred to passage when the water velocity in the fish gate chute were lowest, which occurred when the water levels upstream and downstream of the surge barrier were relatively similar. When the dissolved oxygen upstream of the surge barrier was good, fewer fish passaged downstream to the Wonnerup Inlet although this was a relatively weak effect. However, the dissolved oxygen around the Vasse Suge Barrier during the current analysis period was relatively high compared to other years and therefore we anticipate that the effect of low dissolved oxygen on fish passage would be even stronger in those years. They also preferred to pass downstream through the fish gate during the evening, whereas upstream passages mostly occurred during the dawn and dusk periods.

The findings greatly increase our understanding of the conditions that Black Bream require or prefer to use the fish gate on the Vasse Surge Barrier. However, as the PIT tags last for 20 years, additional data analysis is recommended to compare the factors influencing the passage of the species over multiple years of fish gate operation; including those years that experience poor oxygen levels. It is also recommended that additional fish PIT tagging occur, including other species, so that long-term fish passage through the structure may be further quantified.

Background

The Vasse-Wonnerup Wetland System and its catchment, like many estuaries on the lower-west coast of Western Australia, has been subjected to human activities and is regarded as “extensively modified” (Commonwealth of Australia, 2002, Tweedley et al., 2017b). These modifications have a long history dating back over 100 years and include land clearing, the creation of extensive drainage networks and diversion of rivers that once flowed into the system, and the construction of surge barriers (Tweedley et al., 2017a, Wetland Research & Management, 2007). Moreover, the Vasse-Wonnerup is the “*most grossly enriched major wetland system known in Western Australia*” (McAlpine et al., 1989). High levels of nutrients in this systems have led to the formation of large macroalgal and phytoplankton blooms, some of which contain toxic species, and periods of hypoxia leading to the death of fish (Tweedley et al., 2014, Lane et al., 1997).

Fish kill events in the lower Vasse Wonnerup Estuary have both an ecological and social impact. The most affected large-bodied fishes in recent fish kills have been Black Bream and mullets (sea and yelloweye; Tweedley et al., 2014). The Vasse and Wonnerup surge barriers have fish gates (or chutes) that were intended to enable upstream and downstream fish passage during the drier months of the year (Figure 1). Historically, the fish gates on the surge barriers were opened in response to poor water quality or when fish were observed to be stressed to enable them to move from the Vasse and Wonnerup estuaries to the better water quality conditions in Wonnerup Inlet (Lane et al., 1997). However, very little was known on the movement patterns of these species through the gates.

A previous study by Beatty et al. (2018) was a collaborative project that aimed to determine the broad scale movement of Black Bream and Sea Mullet. The study used acoustic tags internally implanted in 41 Black Bream and nine Sea Mullet. Those tags send out each individual fish’s’ number (like a ‘Morse Code’) that were detected by receivers (‘listening stations’) that were moored within the Wonnerup Inlet, Deadwater and waters upstream of the both the Vasse and Wonnerup surge barriers. This is the same technology used to track the movements of Goldfish in the Lower Vasse River and surrounding water bodies (Beatty et al., 2017). That study on Black Bream suggested that while fish would move, on average, several kilometers a day, those that were located above the Vasse barrier in summer may have not been able to utilise the fish gate to move downstream during later summer and autumn when water quality can deteriorate.

However, the acoustic tags did not determine the fine-scale movements of each fish through the surge barriers. Passive Integrated Transponder (PIT) tags are an ideal way to fill this major gap in knowledge to determine ***when and why*** the fish move through the fish gates. and how these relate to hydrological and other environmental conditions.

PIT tags are similar to the micro-chips that are implanted into dogs and cats. They are small, inexpensive (~$5) and can be implanted quickly (Figure 2) without major surgery and have a working life of >20 years. By setting up PIT antenna at the upstream and downstream end of the fish gate on the Vasse surge barrier, we could determine, the fraction of a second, when each tagged fish passaged through the gates, and even if the passage was unsuccessful. The occurrence and timing of these movements could then be related to environmental factors such as weather patterns, water quality and flow regimes.

This study aimed to determine the spatial and temporal patterns of fish passage through the Vasse fish gate and determine the hydrological criteria and environmental drivers of passage. This information will help with the future operation of the fish gates to enhance fish passage through the surge barriers.

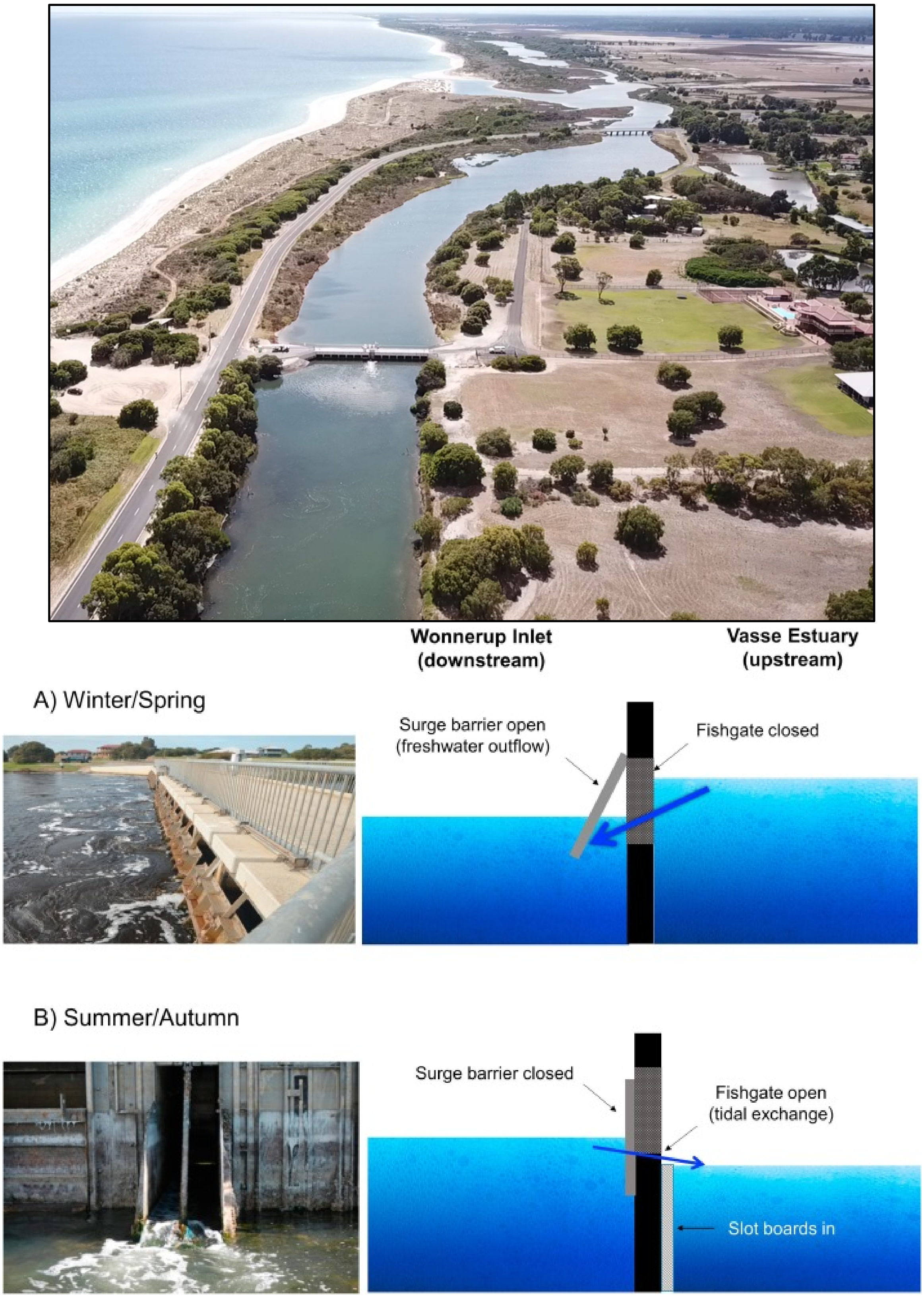

Figure 1. (top) Aerial view of the Vasse Surge Barrier (photo Ash Ramsay, DWER), (bottom) schematic representation of how the surge barriers and fish gates operate.

Methods

The Vasse fish gate was fitted with a custom designed PIT antenna system at both the upstream and downstream ends of its fish gates in April 2017. With the help of local school pupils from Georgiana Molloy SHS and Busselton SHSA and local anglers, a total of 322 Black Bream greater than 100 mm in total length were caught between March 2017 and February 2018. Each fish was tagged using Biomark 12 mm half-duplex pre-loaded PIT tags, inserted into the body cavity (Figure 2).

Fish detection data from each antenna were recorded over 438 consecutive days between 20 March 2017 and 31 May 2018. Each PIT tag detection was classified as either an upstream or downstream passage through the fish gate or an ‘approach’ to the fish gate (Figure 3). Approaches mean that the fish swam close to the antenna at the downstream side of the Vasse fish gate but did not then get detected at the upstream antenna (Figure 3).

A wide range of environmental variables were collected and statistical models used to determine which of those were most important in explaining the patterns of upstream and downstream movements (daily and hourly) and approaches to the fish gate.

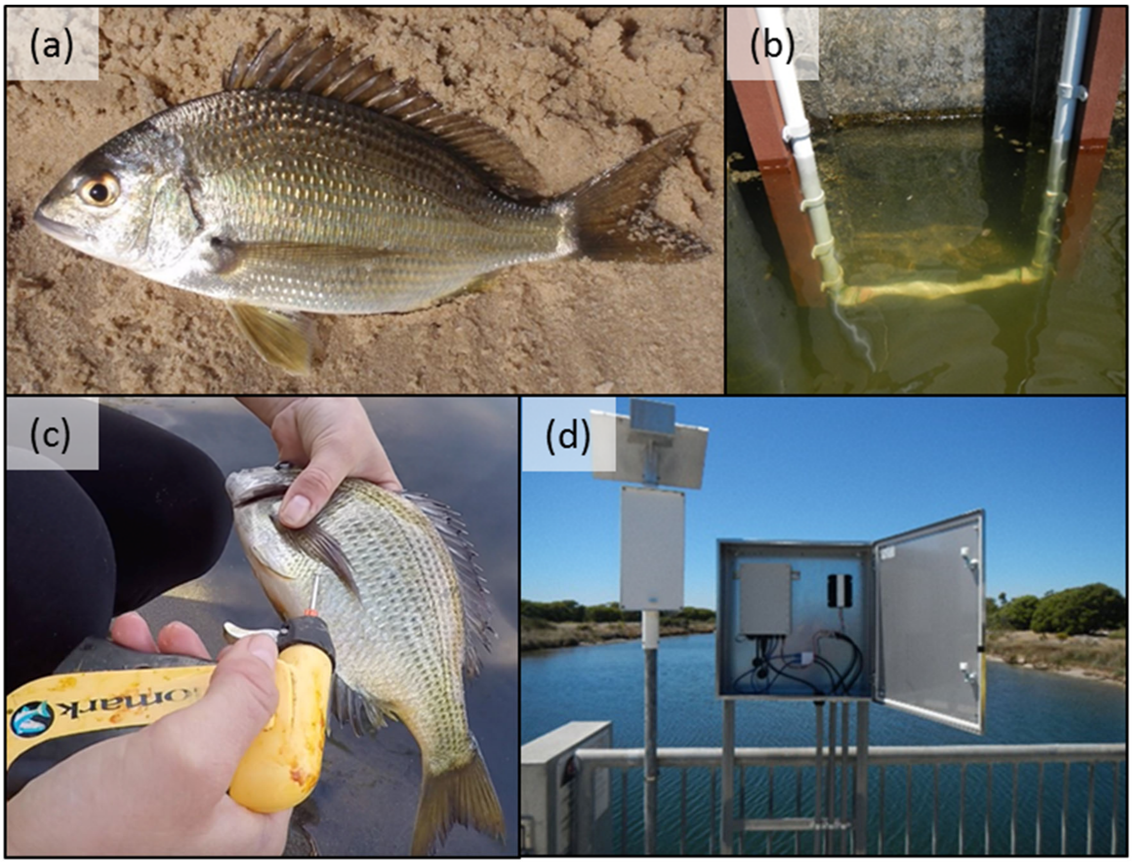

Figure 2. Photographs showing (a) Black Bream, (b) downstream antenna on the fish gate, (c) the insertion of a PIT tag into the body cavity of a Black Bream and (d) the antenna controller equipment.

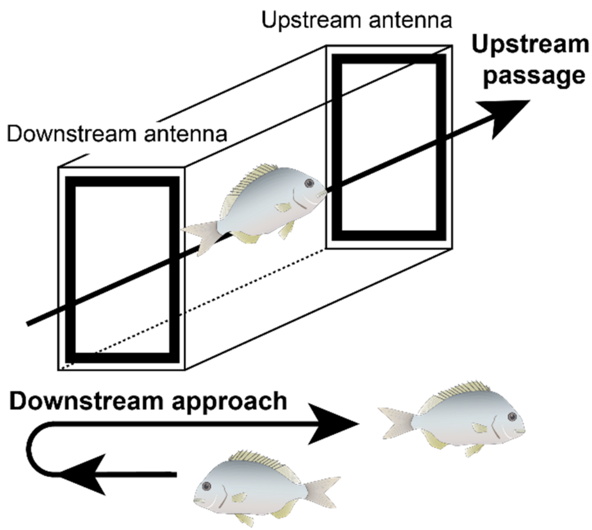

Figure 3: Schematic showing examples of movements of Black Bream through the Vasse fish gate: *Downstream Approach* = PIT tag detected only at downstream antenna. *Upstream passage* = PIT tag detected as downstream then upstream antenna. *Upstream approaches* and successful downstream passages are the reverse of that shown.

Results and discussion

Approaches below the fish gate

The study revealed that most approaches (i.e. detected at the downstream antenna but not actually passaging through the fish gate) by Black Bream occurred in spring 2017 and autumn 2018 (Figure 4). Black Bream usually move upstream to breed, although in the Vasse-Wonnerup they are known breed in the Deadwater. As the approaches to the surge barrier did not coincide with the known spawning period of Black Bream, it is likely that they are also using the surge barrier as a source of food such as grazing on barnacles and other animals attached to the structure. The diet of Bream in the Vasse-Wonnerup typically contains larger quantities of algae and detritus (decaying plant material – e.g. seagrass wrack; Cottingham et al., 2015, 2019) than in other estuaries in south-western Australia (Sarre et al., 2000, Chuwen et al., 2007). As this largely vegetarian diet would be low in calories and large benthic invertebrates (e.g. bivalves) that are the main prey in other estuaries are relatively scarce in Wonnerup Inlet and the Deadwater (Tweedley et al., 2019a, 2019b). Therefore, the surge barrier could provide an important food source for Black Bream and other species such as Yellowtail Trumpeter that were filmed feeding at the structure (Figure 5).

The probability of daily approaches was lowest at both extreme low and high temperatures and also lowest a more extreme salinities, and were highest on days with extreme low and high air pressure.

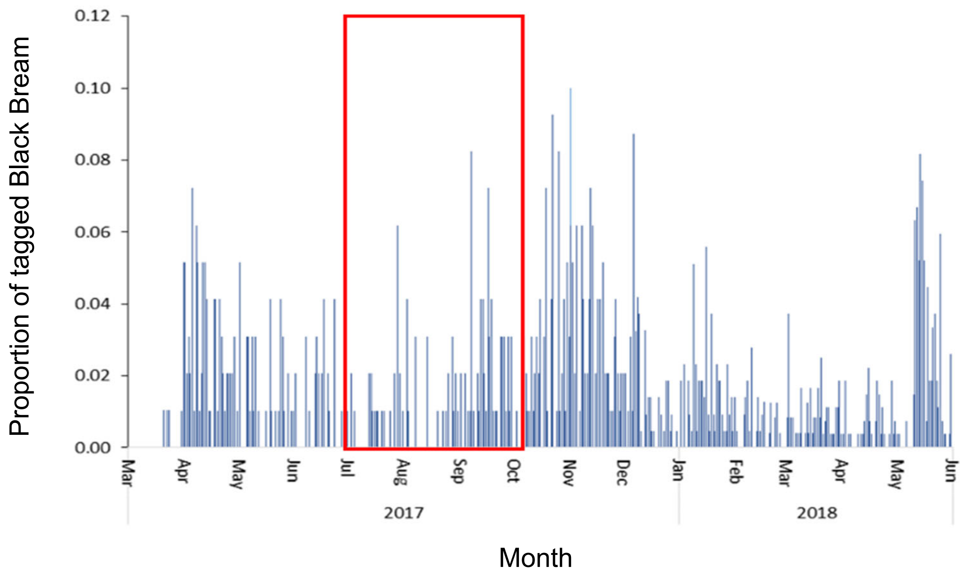

Figure 4: Proportion of tagged Black Bream that approached the Vasse Surge Barrier fish gate (downstream) recorded between 20 March 2017 and 31 May 2018. Note: Typical Black Bream spawning period in the Vasse-Wonnerup is between July and October [red rectangle].

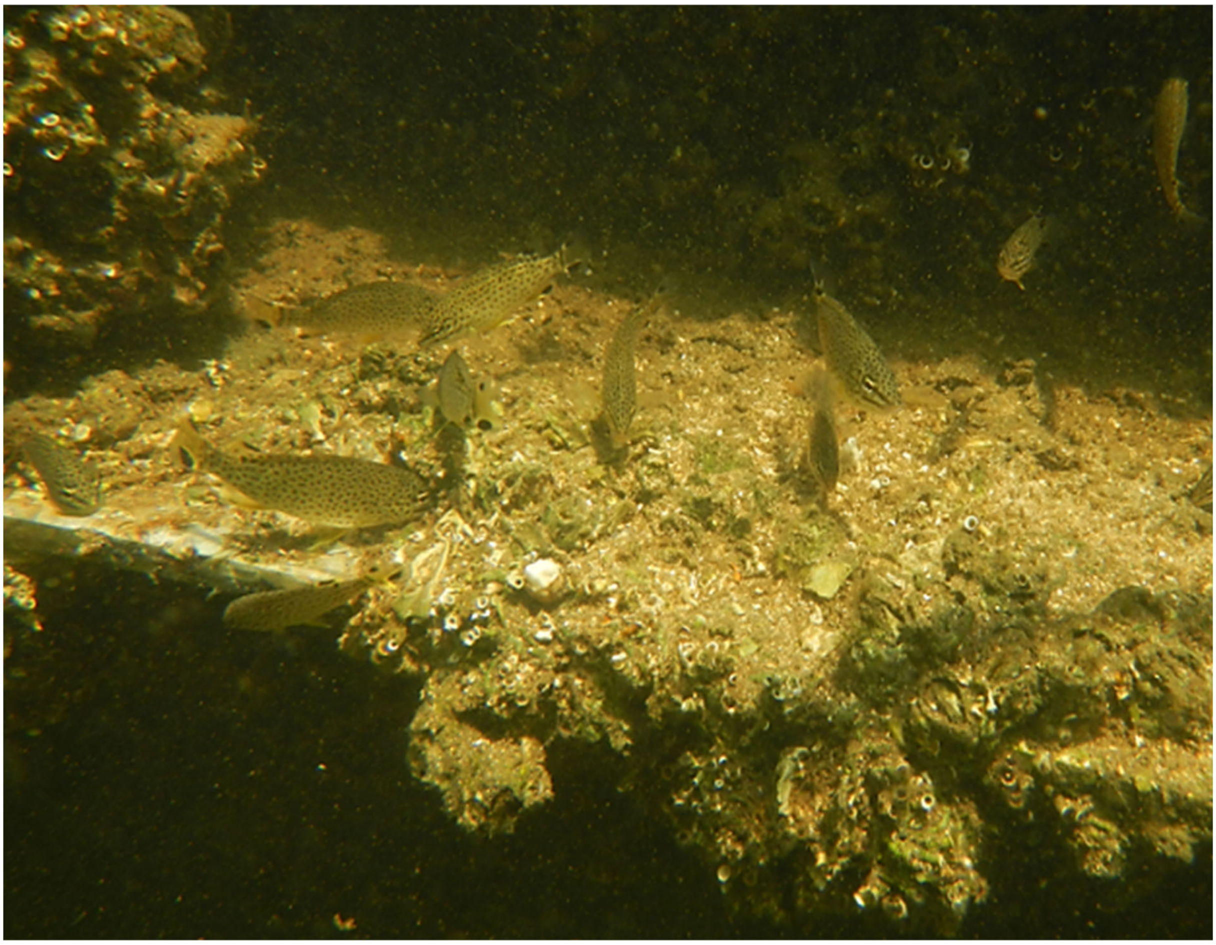

Figure 5: Black Bream and Yellowtail Trumpeter (latter pictured here) use the Vasse Surge Barrier as a source of food and shelter.

Passage through the fish gate

From 1st November 2017 until 31st May 2018, tagged Black Bream passed through the Vasse surge barrier fish gate 440 times (265 downstream and 175 upstream). The overall mean groundspeed of passaging Black Bream was 0.27 m/s and the mean speed through the water (i.e. accounting for velocity at the time of each passage) was 0.40 m/s. The maximum recorded speed of passage was 4.34 m/s, which is quite fast and is the first time that its maximum speed has been estimated in the wild.

Importantly, fish preferred to passage both upstream and downstream when the water velocity within the fish gate was low (i.e. the water levels upstream and downstream of the surge barrier were similar). For example, during passage events the water velocity was average 0.41 m/s compared to 1.09 m/s throughout the entire major passage period (i.e. when the fish gate was operational) (Figure 6).

Along with low velocity conditions, there were certain times of the day when Black Bream preferred to passage through the gates. For upstream passages, Black Bream preferred to passage near to dawn and dusk. For downstream passages, Black Bream passage increased during the evening period (Figure 7). There was also a minor influence of dissolved oxygen levels upstream of the surge barrier; the greater the minimum dissolved upstream, the less likely it was for Black Bream to passage through the fish gates. In other words, when oxygen levels on the Vasse Estuary side of the surge barrier were good, fewer fish moved to the Wonnerup Inlet side. While this effect was not overly strong, the dry season over which the passages took place had relatively good levels of dissolved oxygen compared with other years. It is very likely that during those years that experience more depleted oxygen upstream of the surge barrier, the influence of dissolved oxygen on fish passages would increase.

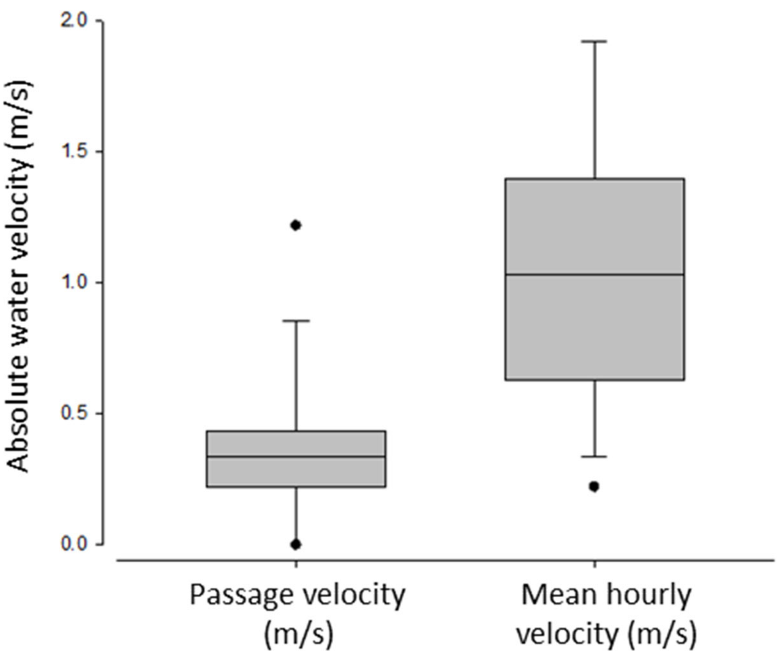

Figure 6: Box plot of absolute water velocity (m/s) within the Vasse Surge Barrier fish gate during fish passage events (left) compared to overall mean hourly water velocity (m/s) (right) over the period that the fish gate was operational.

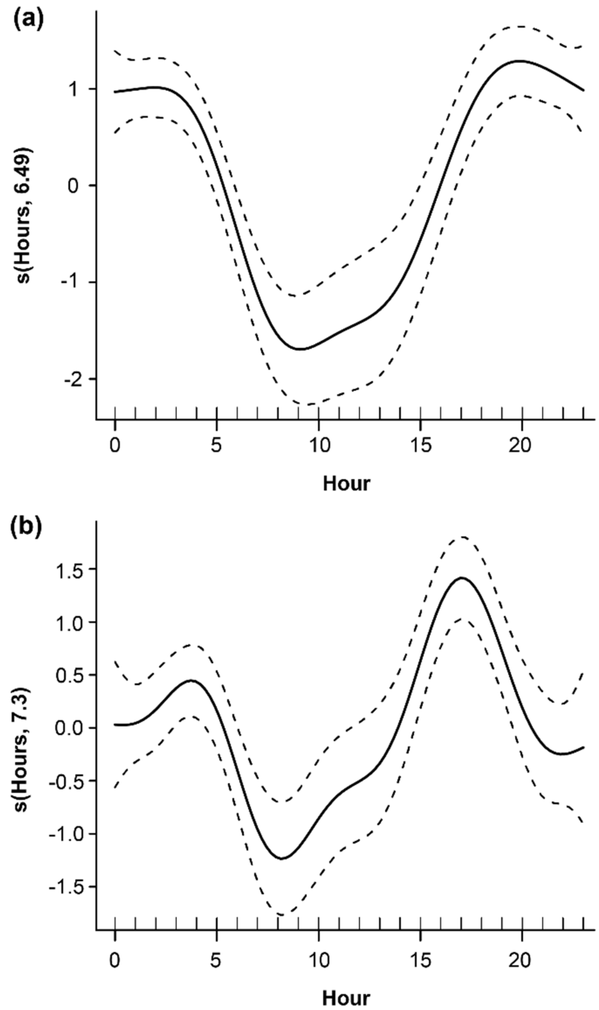

Figure 7. Smoothed effect of hour of the day on hourly proportion of PIT tagged Black Bream that passaged (a) downstream and (b) upstream through the Vasse Surge Barrier fish gate.

Summary and Management Implications

- Black Bream avoid passaging through the fish gate when there are large differences in water levels upstream and downstream of the Surge Barrier.
- They also likely use the surge barrier as a food resource as most approaches were detected outside their breeding period.
- Programming the fish gate to open during times of equalised water levels particularly during the dawn, dusk and evening periods would maximise fish passage.
- The study demonstrates the importance of collaborative research to answer ecological questions relating to the complex Vasse-Wonnerup system including the active participation of citizen scientists to increase community stewardship.
- It is recommended that the data that has continued to be collected from the tagged fish by the PIT monitoring station be similarly analysed and added to this study's dataset.
- There was a weak but significant influence of dissolved oxygen on fish passage. Replicating the study during years that experience poorer dissolved oxygen upstream of the surge barrier would likely reveal a stronger effect of dissolved oxygen on fish passages.
- It is recommended that additional tagging occur of Black Bream and other species of adequate body size that can safely be PIT tagged (i.e. >100 mm TL), such as Yellowtail Trumpeter and Sea Mullet, in order to further increase the knowledge of fish passage through the fish gate.

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